A nanoelectrode array according to the invention (see figure) would include two or more microelectrode pads on an electrically insulating substrate. The sizes of the microelectrode pads and the distances between them could range from as little as about a micron to as large as hundreds of microns, the exact values depending on the intended use. Each microelectrode pad could be electrically addressed, either individually or in combination with one or more other pads for localized stimulation and/or recording. Each microelectrode pad would support either a stimulating or a recording electrode. In either case, the electrode would comprise a subarray of multiple nanoelectrodes in the form of carbon nanotubes electrically connected to, and protruding perpendicularly from, a metal contact layer on an electrically insulating substrate.

In the case of a stimulating electrode, the protruding portions of the carbon nanotubes would be treated to deposit a thin electro-active coating layer that would impart the desired amount of pseudocapacitance. Depending on the application, the exposed surface of the metal contact layer between the nanoelectrodes would be coated with an electrically insulating material (e.g., silica or a nonconductive polymer), or with an electrically conductive or electro-active polymer.

In the case of a recording electrode, it is desirable to minimize the size of the electrically exposed portion of each carbon nanotube so as to maximize the degree of localization and to minimize noise (thereby maximizing sensitivity). Therefore, an insulating layer would be deposited to sufficient thickness that only the tip(s) of the longest carbon nanotube(s) would protrude.

The term carbon nanotube here covers a general class of carbon materials, including multi-walled carbon nanotubes (MWCNTs) and nanofibers (CNFs). These nanostructured carbon materials have physical and chemical properties that make them especially suitable for use as nanoelectrodes according to this invention. Well-aligned arrays of MWCNTs/CNFs have been grown by plasma-enhanced chemical vapor deposition on metal lines that have been pre-patterned by use of lithographic techniques. A previously published "bottom-up" scheme for fabricating an array of MWCNTs/CNFs that protrude from metal lines embedded in an SiO_2 matrix has been adopted as the basis of a scheme for fabricating nanoelectrode arrays according to the invention. The fabrication processes involved in these schemes are compatible with those used in manufacturing semiconductor devices. Hence, it should be possible to fabricate the nanoelectrode arrays at relatively low cost.

This work was done by Jun Li and M. Meyyappan of Ames Research Center and Russell Andrews, an Ames associate.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Innovative Partnerships Office at (650) 604-2954. Refer to ARC-15062-1.

Compact Directional Microwave Antenna for Localized Heating

Heating is concentrated on one side.

Lyndon B. Johnson Space Center, Houston, Texas

A directional, catheter-sized cylindrical antenna has been developed for localized delivery of microwave radiation for heating (and thus killing) diseased tissue without excessively heating nearby healthy tissue. By "localized" is meant that the antenna radiates much more in a selected azimuthal direction than in the opposite radial direction, so that it heats tissue much more on one side than it does on the opposite side. This antenna can be inserted using either a catheter or a syringe. A 2.4-mm prototype was tested, although smaller antennas are possible.

Prior compact, cylindrical antennas designed for therapeutic localized hyperthermia do not exhibit such directionality; that is, they radiate in approximately axisymmetric patterns. Prior directional antennas designed for the same purpose have been, variously, (1) too large to fit within catheters or (2) too large, after deployment from catheters, to fit within the confines of most human organs. In contrast, the present antenna offers a high degree of directionality and is compact enough to be useable as a catheter in some applications.

The antenna design is a hybrid of monopole-antenna and transmission-line design elements. The antenna (see Figure 1) is formed from an open-ended coplanar waveguide in which the gap between the middle conductor strip and the two outer (ground) conductor strips tapers from (1) a smaller value more characteristic of a transmission line to (2) a larger value more characteristic of a leaky transmission line or an antenna. The coplanar waveguide is wrapped around a polytetrafluoroethylene (PTFE) tube, and its abutting edges are soldered together to form the

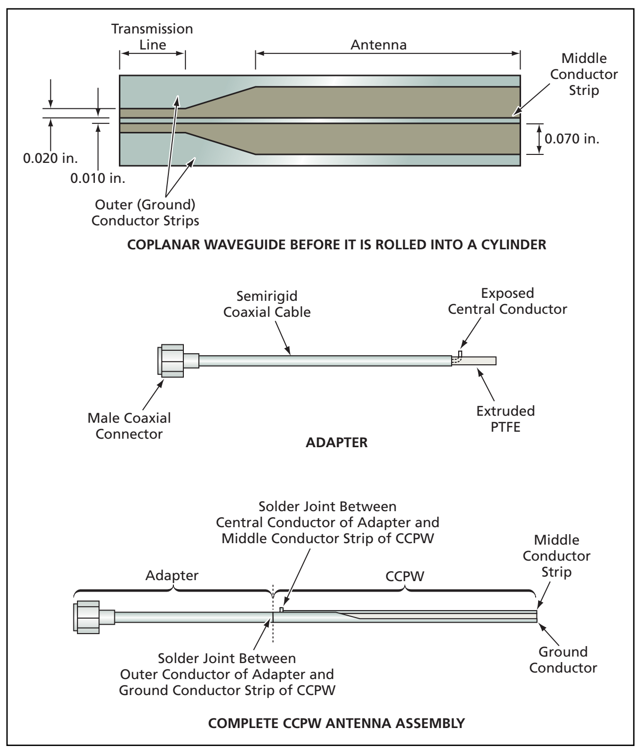

Figure 1. A **Coplanar Waveguide With a Taper** is rolled into a cylinder and joined with a coaxial-cable adapter to form a narrow antenna that radiates predominantly to one side.

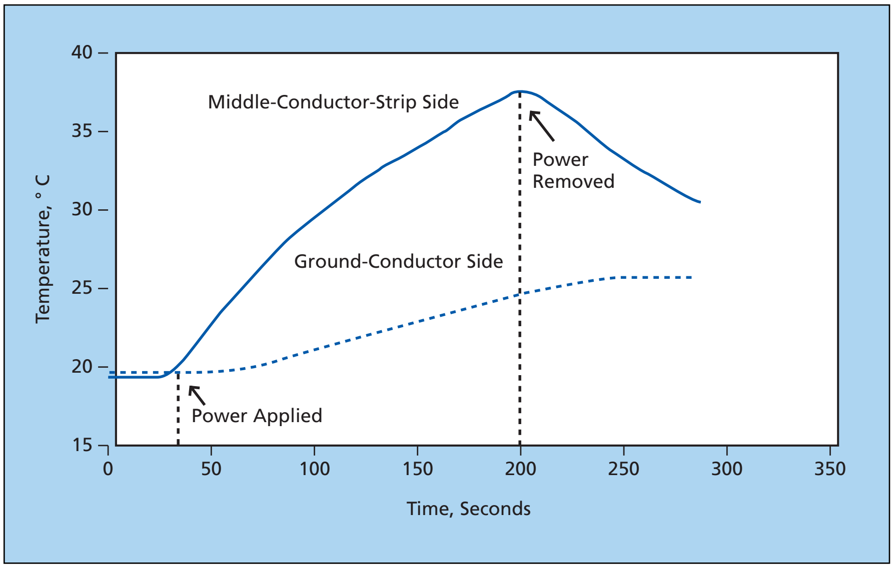

Figure 2. The **Temperature Rises on Opposite Sides** of the antenna were unequal, as desired, in a mass of simulated tissue heated with microwave power by use of the antenna.

cylindrical antenna structure, now denoted a cylindrical coplanar waveguide (CCPW), in which there is only one ground conductor. In operation, the wide-gap region between the middle conductor strip and the ground conductor permits radiation into the top side, while the larger ground side limits radiation on the back side.

For a test of directionality, the antenna was inserted in a piece of biomedical simulation material, called "phantom" in the art, formulated to have thermal and electromagnetic properties similar to those of human tissue. The phantom was instrumented with two fiber-optic temperature probes: one at 3 mm radially outward from the middle conductor of the CCPW and one 3 mm radially outward from the ground conductor on the opposite side. The catheter was excited with a power of 5 W at a frequency of 2.45 GHz. The temperature measurements, plotted in Figure 2, showed that, as desired, there was considerably more heating on the middle-conductor side. As indicated in Figure 2, the temperature difference between the targeted direction and the back side is about 13°C. This difference is sufficient to provide localized ablation (killing of targeted diseased cells) while preserving the healthy tissue.

This work was done by Patrick W. Fink, Gregory Y. Lin, Andrew W. Chu, Justin A. Dobbins, G. Dickey Arndt, and Phong Ngo of Johnson Space Center.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23781.

Using Hyperspectral Imagery To Identify Turfgrass Stresses

Stress maps could enable more-efficient management of large turfgrass fields.

Stennis Space Center, Mississippi

The use of a form of remote sensing to aid in the management of large turfgrass fields (e.g. golf courses) has been proposed. A turfgrass field of interest would be surveyed in sunlight by use of an airborne hyperspectral imaging system, then the raw observational data would be preprocessed into hyperspectral reflectance image data. These data would be further processed to identify turfgrass stresses, to determine the spatial distributions of those stresses, and to generate maps showing the spatial distributions.

Until now, chemicals and water have often been applied, variously, (1) indiscriminately to an entire turfgrass field without regard to localization of specific stresses or (2) to visible and possibly localized signs of stress — for example, browning, damage from traffic, or conspicuous growth of weeds. Indiscriminate application is uneconomical and environmentally unsound; the amounts of water and chemicals consumed could be insufficient in some areas and excessive in most areas, and excess chemicals can leak into the environment. In cases in which developing stresses do not show visible signs at first, it could be more economical and effective to take corrective action before visible signs appear. By enabling early identification of specific stresses and their locations, the proposed method would provide guidance for planning more effective, more economical, and more environmentally sound turfgrass-management practices, including application of chemicals and water, aeration, and mowing.

The underlying concept of using hyperspectral imagery to generate stress maps as guides to efficient management of vegetation in large fields is not new; it has been applied in the growth of crops to be harvested. What is new here is the effort to develop an algorithm that processes hyperspectral reflectance data into spectral indices specific to stresses in turfgrass. The development effort has included a study in which small turfgrass plots that were, variously, healthy or subjected to a variety of controlled stresses were observed by use of a hand-held spectroradiometer. The spectroradiometer readings in the wavelength range from 350 to 1,000 nm were processed to extract hyperspectral reflectance data, which, in turn, were analyzed to find correlations with the controlled stresses. Several indices were found to be correlated with drought stress and to be potentially useful for identifying drought stress before visible symptoms appear.

This work was done by Kendall Hutto and David Shaw of Mississippi State University for Stennis Space Center.

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